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AUTHOR Baker, Linda
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ABSTRACT

Four experiments examined the effect of input sequence on memory for simple stories. After reading stories written in either chronological or flashback sequence, subjects made a decision about the underlying order of occurrence of two events. Responses were consistently faster and more accurate on chronological sequences under three conditions of testing: immediately after reading, after a ten-second unfilled interval, and after a ten-second filled interval. It was also shown that decisions about input order were easier than decisions about underlying order when the stories contained flashbacks. These data indicate that subjects based their responses on a memory representation which preserved the input sequence of events. An additional finding was that decisions were easier when the events in the story had a logical progression rather than an arbitrary ordering, demonstrating an influence of prior knowledge. (Author)

CENTER FOR THE STUDY OF READING

Technical Report No. 84

PROCESSING TEMPORAL RELATIONSHIPS IN SIMPLE STORIES: EFFECTS OF INPUT SEQUENCE

Linda Baker

University of Illinois at Urbana-Champaign

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University of Illinois
at Urbana-Champaign
51 Gerty Drive
Champaign, Illinois 61820

Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

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Processing Temporal Relationships in Simple Stories: Effects of Input Sequence

All of our experiences with words occur over time due to the sequential nature of language. The question of interest in the present paper is the extent to which real-time order information influences memory for simple stories. A story is an ideal discourse structure to use in this context because its representation is temporally marked in two ways: 1) it is encoded over time, and 2) it contains explicit or implicit information about the temporal sequence of events within the story itself (story time).

In most texts, input order (real time) is perfectly confounded with story time in that the order of presentation of the events is the same as the order in which they occur in the story. When the temporal organization of the story matches the temporal record of the input, it should be relatively easy to represent the order of events in memory. The representation problem becomes more complex when story time is inconsistent with real time, e.g., when the story contains a flashback. Here, readers cannot rely on an episodic temporal record of experience to provide information about the ordering of events in the story, but must try to keep track of the inversions.

The sentence memory literature provides some evidence that this inconsistency would pose a problem. Clark and Clark (1968) presented subjects with 2-event sentences connected by temporal adverbs and cued them for verbatim recall. In general, sentences were more poorly recalled when the order of input was different from the underlying order of occurrence. Using the same stimulus materials, Smith and McMahon (1970) asked subjects to report what happened first or second immediately after presentation of a sentence. Longer response times resulted when order of input differed from order of occurrence.

These experiments suggest that the temporal order of input dominates the memory code for single sentences. However, the general consensus in the prose literature is that surface characteristics of a text, including order of input, have little bearing on the memory representation (e.g., Kintsch, 1974). Several experiments have demonstrated that subjects tend to recall semantically related ideas together even if they had not been presented together at input (Mandler & Johnson, 1977; Meyer & McConkie, 1973; Meyers & Boldrick, 1976; Stein & Nezworski, in press; Thorndyke, 1977). Such reorganization could, of course, occur at retrieval and does not necessarily reflect the structure of the memory representation. However, Kintsch and Monk (1972) and King and Greeno (1974) obtained evidence for constructive processing using a response time paradigm. They concluded that people extract the main ideas from a text and create a coherent, well-structured representation as they are reading.

The present series of experiments takes issue with this exclusive focus on meaning, specifically, the contention that surface characteristics are lost during the effort to construct a coherent semantic interpretation. This focus characterizes several memory models which assume the semantic representation is invariant under paraphrases of the same information

(Anderson & Bower, 1973; Kintsch, 1974; Norman & Rumelhart, 1975; Schank, 1972). Such models would presumably represent information in the same abstract propositional format regardless of the specific temporal adverbial that is used. For example, the sentences, "Bill cut the grass. Before that, he went to the store" and "Bill went to the store. Then he cut the grass," should entail formally equivalent representations.

This invariance assumption underlies linguistic models which explicitly consider the temporal relations existing among events in a story. For example, van Dijk (1972) suggests that when reading text, referential/real time points and intervals are mapped onto semantically represented times. Each event is mapped onto a sentoid representing an abstract idea, along with its corresponding time indicator. Even if the direct relationship between real time (input order) and semantic time (underlying order) does not obtain, the mapping is still the same. Similarly, Miller and Johnson-Laird (1976) suggest that incoming events are mapped onto a conceptual time line. In other words, inconsistencies between real time and underlying story time are resolved in favor of story time.

Existing story grammars also emphasize the dominance of the underlying order of events (Mandler & Johnson, 1977; Stein & Glenn, in press). One of the major assumptions of a story grammar is that a story has a canonical order. If a story violates the expected temporal order of events, people attempt to re-organize the information to conform to the canonical story schema. Evidence in support of this argument has been provided by Mandler (in press), Stein and Nezworski (in press), and Kintsch, Kozminski, and

Mandel (1977). These investigators presented subjects with stories containing various temporal disruptions and then asked for recall or summarization of the stories. In general, subjects produced protocols that bore a closer resemblance to the ideal story sequence than to the actual input sequence. Although it may be tempting to argue that this reorganization occurs during encoding, conclusive evidence is lacking.

In summary, virtually all of the studies examining memory for prose have focused on the construction of a meaningful, well-integrated representation and have ignored the possible contributions of surface information. The goal of the present experiments is to demonstrate that certain surface characteristics, specifically, the order of input, do in fact exert an influence on memory. The basic paradigm involved presenting subjects with paragraph-length stories written in either chronological or flashback sequence. After reading each story, subjects were asked to decide if the order in which two events were displayed in a probe matched the underlying order of occurrence in the story.

If the memory representation preserves the order of input, then subjects should be faster and more accurate making decisions on chronological stories than on flashback stories. This advantage would be due to the fact that input sequence is identical to underlying sequence in chronological stories, but subjects must figure out the underlying sequence of events before they can respond on flashback stories. On the other hand, if the representation is integrated during processing to conform to the underlying sequence of events, then performance on flashback stories should not differ from chronological. Such an outcome would be consistent with the contention that subjects extract and represent the same meaning from different surface expressions of similar ideas.

Four experiments will be reported which seek to demonstrate better access of input order relationships than temporal relationships existing in the meaning of the story. In the first experiment, subjects were tested immediately after reading the story. The second experiment introduced a brief interval between study and test to provide an opportunity for "consolidation" of the representation, while an interference task was used in Experiment 4 to disrupt verbatim memory. A somewhat different procedure was used in Experiment 3, where decisions about flashback stories were based on either the underlying order in story time or on real-time input order. (Throughout the paper, the terms "real time" and "input order" will be used interchangeably, as will "story time" and "underlying order.")

In addition to the chronological-flashback manipulation, the experiments also varied the type of connection existing among the events in the stories. Some stories contained an arbitrarily-ordered series of events, with no semantic constraints on the ordering. The remaining stories contained events which followed a logical progression but were not causally related. It was expected that decisions would be faster and more accurate on logically-ordered stories because they conform to past experience. This advantage could arise because the semantic constraints facilitated the construction of a well-integrated representation at encoding. The advantage could also originate at retrieval; prior knowledge can be used to facilitate decisions on logical orderings, whereas on arbitrary orderings, subjects can only use information encoded during the experiment.

The encoding explanation also predicts an interaction between sequence and connection; it should be easier to reorganize logical flashback stories to conform to the underlying sequence than arbitrary flashback stories. Thus, an interaction would provide additional evidence that subjects attempted to construct an integrated representation during processing. Similar predictions have received support from Kintsch et al. (1977) and Brown and Murphy (1975).

Experiment 1

Method

Stories. The stimulus materials consisted of 76 simple stories, each about 60 words in length. Each story described a series of three events experienced by a protagonist in a particular situation. The stories were all of similar structure; there was an introductory setting statement, followed by three sentences, each of which described one major event. The fifth and final sentence contained a concluding comment of some sort.[1]

Each story was originally written in chronological sequence such that the order the events were mentioned was the order they occurred in the story. The temporal contiguity between events was always made explicit by markers such as "Next," "Then," "A short time later." The stories were rewritten into flashback versions, where order of mention differed from order of occurrence. Only one event was involved in the flashback, and it was always mentioned immediately after the event which had actually followed it in the story. The flashback was typically signalled by the phrase, "Before that," where all references to the previous event were pronominal. Since each story had three events, there were two possible flashback sequences, given the above constraints. The flashback reversed the order of mention of either the first and second events or the second and third. Half of the stories contained one type of flashback and half the other. This manipulation was included in order to prevent subjects from knowing in advance which two events would be involved in the flashback and therefore focusing their attention on those two events. It should be noted that the untested first and last sentences served to eliminate possible end-anchor effects (c.f. Potts, 1975).

In addition to the chronological-flashback variable, the stories differed with respect to the type of connections existing between the events. In half of the stories, the three events were independent. Although they were related to a particular theme, there were no logical connections between them. Thus, the three events could be rearranged in any order without affecting the meaningfulness of the story. In the remaining stories, the order of events was semantically constrained. Strictly speaking, the events were not causally related, but they did have an expected sequence based on knowledge of the "script" (Schank, 1975) for the situation. The two types of connections will be designated "arbitrary" and "logical," respectively, but the term "logical" should not be misunderstood as entailing a CAUSE relationship. Both types of connections can be represented formally by THEN relations (c.f. Mandler & Johnson, 1977), but the logical are more constrained than the arbitrary. Examples of the stories are presented in Table 1.[2]

In making up the set of materials to be used in the experiment, half of the stories containing each type of connection were randomly selected to appear in flashback version, half in chronological. Ten stories were designated as practice items, and 10 as filler items. The remaining 56 stories, 14 of each of the four types, were randomly arranged for the test stimulus set, with the filler items evenly interspersed among them.

Insert Table 1 about here

Probes. A test probe was constructed for each story and consisted of two phrases separated by 10 dots. Each phrase was sufficient to specify one event in the story. The subjects' task was to decide if the order of the phrases (from left to right) was the same as the order those events took place in the story. Examples of the probes are included in Table 1. The probes were presented as phrases rather than as complete sentences in order to simplify the task requirements and to reduce the possibility of verbatim matches with the surface form of the text. Sixty percent of the probes were true with respect to the story and 40% were false.

The two events included in the probe were the two events inverted by the flashback, or, in the case of chronological sequences, the two events that were inverted in the corresponding flashback version. Since subjects could conceivably adopt a strategy of anticipating the probe on the basis of the inverted events, 10 fillers were included. Here, the probe tested the temporal relationship between the first and third events, rather than the combination of events involved in the flashback.

Equipment. Stimulus presentation was under the control of a PDP-11/40 computer. The stories were displayed in upper case letters on 9-inch video monitors at seven individual subject stations. The entire story was presented on the screen at one time, followed by the probe. Each station was equipped with two response buttons. The right button was labeled "true" and the left was labeled "false." Responses and response latencies were recorded by the computer.

Design. A 2 x 2 within-subjects design was used, with two story sequences (flashback or chronological) and two types of connections between events (arbitrary or logical). Nineteen Rutgers College students participated in the experiment as part of a general psychology course requirement.

Procedure. Subjects were told that they would be reading a series of short stories, each containing an ordered sequence of three main events. They were also told that sometimes the events would be mentioned in the order they occured in the story, but that sometimes the events would be mentioned out of sequence, as in a flashback. The probes were then described, and subjects were instructed to base their responses on the underlying order of events, that is, the order that the characters in the story experienced the events. It was emphasized that this order would sometimes be different from the order of mention. Subjects were instructed to press the "true" button if the probe matched the underlying order in the story, and to press "false" if not. They were asked to respond as quickly and as accurately as possible. The experimenter read a sample flashback story and probe, carefully explaining what the correct response would be and why. The connection manipulation was not mentioned in the instructions as this knowledge was not deemed necessary.

After answering any questions the subjects had, ten practice trials were administered. Each story was presented for 20 seconds, which was sufficient time to read through the story once. The probe appeared 1.5 seconds later and remained on the screen for 9 seconds or until all subjects responded, whichever came first. The experimenter monitored the performance of the subjects during the practice trials, and provided feedback about their general performance levels. After ascertaining that all subjects were comfortable with the task, the test trials were begun. Again, each story was presented for 20 seconds followed by a probe for a maximum of 9 seconds. There were two 2-minute rest periods during the experiment. The entire session lasted about 50 minutes.

Results and Discussion

The data obtained in all experiments were treated in a similar fashion. The following general comments pertain to all analyses. Response times and error rates were subjected to separate 2 x 2 analyses of variance, with story sequence (chronological or flashback) and type of connection (arbitrary or logical) as factors. Each dependent variable was analyzed twice, once with subjects as the random factor and once with items. Because of the limited number of items per condition and because of the relatively high error rates, it was not feasible to enter both subject and item effects into a single analysis. Moreover, the complete lack of random selection of stimuli prohibits generality beyond the present sample, and yet an analysis collapsing over subjects provides assurance tha[illegible]ts are at least robust within this sample. To facilitate presentation of the results, $\underline{F}$ ratios from the subject analyses will be designated $\underline{F}_1$, those from the item analyses, $\underline{F}_2$. The rejection region is $\underline{p} < .05$ for all tests. True and false decisions were analyzed separately, and the pattern of results was quite similar. In the interest of brevity, the false judgments will not be discussed in the text. However, the means on false decisions will be presented in the appropriate tables along with the true decisions. A summary of the relevant statistical tests on false judgments can be found in the appendix.

The mean response times on correct decisions are given in Table 2, with the corresponding error probabilities indicated in parentheses. (All means represent subject means.) Analyses of variance of response times on true

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Insert Table 2 about here

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decisions revealed a reliable effect of sequence, $\underline{F}_1(1,72) = 6.14$, $\underline{MS}_e = 538,137$; $\underline{F}_2(1,26) = 4.96$, $\underline{MS}_e = 345,169$. As expected, latencies were considerably longer on probes for flashback sequences than for chronological. This suggests that the initial representation of the story was organized according to input sequence. It takes time to calculate the correct event sequence if underlying order differs from surface order. Although the response times in Table 2 suggest an advantage of logical connections over arbitrary, neither analysis of variance reached conventional significance levels. There was no evidence of an interaction between story sequence and type of connection.

Analyses of the error data reveal parallel effects. The main effect of sequence was reliable, $\underline{F}_1(1,72) = 7.37$, $\underline{MS}_e = .0183$; $\underline{F}_2(1,26) = 9.50$, $\underline{MS}_e = 2.63$.[3] More errors were made on decisions about flashback sequences than on chronological, reflecting a tendency to respond on the basis of input order rather than underlying order. The main effect of connection was also reliable, $\underline{F}_1(1,72) = 5.32$, $\underline{MS}_e = .0183$; $\underline{F}_2(1,26) = 6.01$, $\underline{MS}_e = 2.63$, confirming expectations. Errors were more likely when the events in the story were arbitrarily ordered than when they were logically related. As with response times, there was no evidence of an interaction.

The results obtained in the present experiment demonstrate that the initial representation of a story is affected by the temporal order of input. If real time and story time are consistent, as they are in chronological paragraphs, subjects are faster and more accurate in responding than if they are inconsistent. In addition, the experiment demonstrates a role of prior knowledge such that if the sequence of events follows a logical progression, decisions about order are facilitated.

It is possible that subjects were trying to create a semantically integrated representation, but with an immediate test they may not have had time to sort out the story time relations. If this is true, perhaps differences between chronological and flashback sequences would be eliminated if subjects are given additional time after reading the passage to reorganize their internal representation of the story. On the other hand, if subjects are satisfied with a real-time ordering of their representation, then a brief delay should not change the pattern of results. Experiment 2 was addressed to this question.

Experiment 2

Method

The experiment was identical to Experiment 1 in all respects, except that a 10-second unfilled interval was introduced between story and probe presentation. Subjects received the same instructions, but they were also explicitly encouraged to establish and rehearse the story-time ordering of events during the interval. Ten Rutgers College students participated in the experiment in partial fulfillment of a general psychology course requirement. The experiment lasted about 60 minutes.

Results and Discussion

Mean response times for correct decisions are presented in Table 3, with corresponding error rates indicated in parentheses. Analyses of response latencies on true decisions revealed a reliable effect of sequence, $F_1(1,36) = 7.25$, $MS_e = 312,716$; $F_2(1,26) = 6.77$, $MS_e = 241,899$. As in Experiment 1, response times on flashback sequences were consistently longer than on chronological. The connection effect also replicates Experiment 1,

$F_1(1,36) = 5.04$, $MS_e = 312,716$; $F_2(1,26) = 5.61$, $MS_e = 241,899$; logical

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Insert Table 3 about here

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relations among events facilitate decisions about order. There was no evidence of an interaction between sequence and connection.

The introduction of an unfilled interval did not eliminate or even reduce the differences between chronological and flashback stories. Input sequence still seems to be the primary basis of organization in memory. If the data from the two experiments are combined, treating retention interval as a between-subjects factor, the effect of interval is reliable, $F_1(1,27) = 5.87$, $MS_e = 1,291,832$; latencies were longer on the delayed test than on the immediate test. This difference probably arose because the delay subjects were not sure exactly when the probe would be presented and so had slower reaction times (cf. Kahneman & Henir, 1977). Of more importance than the main effect, however, was the lack of any interactions with interval. Thus, although subjects required more time to respond on the delayed test, the retention interval did not differentially influence performance.

Analyses of the error data revealed a reliable effect of sequence, $F_1(1,36) = 12.58$, $MS_e = .01312$; $F_2(1,26) = 7.93$, $MS_e = 1.49$, with more errors on flashback stories than on chronological. Providing subjects with additional time to think about the story did not reduce error rates on flashback sequences relative to the immediate test. The effect of connection was not reliable, nor was there an interaction between sequence and connection.

The results of this experiment essentially replicate those obtained in Experiment 1, further attesting to the organizing influence of the temporal record of input. The results on the immediate test might be explained by claiming that subjects simply did not have time to fully integrate the material before being tested. However, the extra 10 seconds of unfilled time in Experiment 2 should have allowed a semantically integrated representation if this was the subject's goal. Clearly, subjects did not create such an integrated representation either during processing or in the unfilled interval after reading. The delayed results are all the more surprising given that subjects were explicitly told to think about the underlying order of events during the retention interval. It could be argued that subjects did not follow instructions and rehearsed the events in their order of presentation, even when it was not always to their advantage. However, this strategy would not be adopted unless it was easier to deal with episodic order information than with meaning. This is, in fact, what the present paper is trying to demonstrate empirically.

Experiment 3

The data from Experiments 1 and 2 are certainly consistent with the idea of a temporal organization in memory. However, the differences in responses to chronological and flashback sequences have at least one alternative explanation. Perhaps two representations are established when reading a story. One representation might be ordered by real time to preserve a record of the input, and the other might be an abstracted semantic representation that would provide a more permanent logical record of events. This second record would presumably be ordered by story time as opposed to real clock time. In the case of a chronological input story, the two representations would be completely redundant. However, with flashback stories, there would be a discrepancy between the two memory records. The presence of two conflicting representations might retard decisions and increase errors.

In view of this alternative interpretation, the data do not unequivocably demonstrate that the stories are represented in memory according to the temporal order of input. A more definitive test would entail separate assessments of memory for real time and story time. This task was undertaken in the present experiment by presenting subjects with flashback stories and requiring an order decision about either the order of occurrence in story time or the order of mention in real time. If two equally accessible representations do exist, one would expect no differences in performance because a flashback creates a conflict in both situations. That is, a real-time response requires subjects to ignore the underlying story-time sequence, while a story-time response requires them to ignore the real-time order of input.

However, if the initial representation is organized according to input sequence, then subjects should be faster making a decision when they are told to use real time as the basis of the answer, even though they must ignore the semantic markers signalling the occurrence of a flashback. Such an outcome would not, of course, rule out the existence of a semantic representation, but it would demonstrate the advantage of a temporally organized record.

Method

Materials. The stimulus materials were the same as those used in the preceding experiments, except that all stories appeared in their flashback versions. The test probes were also the same, but the proportion of true and false decisions was 50-50 rather than 60-40.

Design. The design was a 2 x 2 x 2 mixed factorial. The within-subjects factors were type of connection between events (arbitrary or logical) and test question (real-time or story-time). The between-subjects factor was block order. One group of subjects received real-time questions on the first half of the trials and story-time questions on the second half (R-S). A second group received story-time questions on the first trial block and real-time questions on the second (S-R). The order of presentation of the stories was constant across block orders; thus, block order was a within-items factor. A total of 28 subjects participated in the experiment, drawn from the Rutgers introductory psychology subject pool. There were 11 subjects in Block R-S and 17 subjects in Block S-R.

Procedure. Subjects were informed that all of the stories they would be reading contained flashbacks and that the ordering of the events was particularly important. They were told that on half of the trials, they would be expected to base their answer to the probe on the order that the events were mentioned in the text, and on the remaining trials, they should respond according to the order the events took place in the story itself. A sample story was presented, along with sample probes. Care was taken to make sure that subjects understood the task, particularly the distinction between real time and story time.

The procedure was basically the same as in Experiment 1. The story was presented for 20 seconds followed after 1.5 seconds by the probe. The first five practice trials required real-time responses, the last five were based on story time. The test trials were preceded by a message instructing subjects to base their answers on either real time or story time until instructed otherwise. After half of the trials had been presented, subjects were given a 3-minute rest period. They were then instructed to base their answers to the remaining probes on story or real time, whichever question type they did not receive in the first trial block. The entire experiment lasted about 60 minutes.

Results and Discussion

The mean response times and error probabilities are presented in Table 4. The question of primary interest was whether real time decisions are easier than story time decisions. Analyses of the true response latencies provided an affirmative answer.' The effect of test question was reliable, $\underline{F}_2(1,26) = 18.66$, $\underline{MS}_e = 380,783$; $\underline{F}_2(1,45) = 8.61$, $\underline{MS}_e = 319,468$, with faster responses when decisions were based on input order. However, the magnitude of this effect depended both on the type of connection existing between the events and the order in which the two types of test questions were presented.

Insert Table 4 about here

This is indicated by the triple interaction of question x connection x block, $F_1(1,26) = 7.74$, $MS_e = 240,056$; $F_2(1,45) = 4.30$, $MS_e = 319,468$. This interaction also qualifies the effect of connection, $F_1(1,26) = 4.39$, $MS_e = 241,641$, its interaction with question, $F_1(1,26) = 8.74$, $MS_e = 240,056$, and its interaction with block, $F_1(1,26) = 15.57$, $MS_e = 241,641$; $F_2(1,45) = 7.45$, $MS_e = 319,468$.

These interactions can be expressed verbally as follows: If real time was tested before story time (Block R-S), response times on logical and arbitrary stories were roughly equivalent. If story time was tested first (Block S-R), arbitrary paragraphs were faster than logical. However, this effect occurred primarily when the test question was based on real time. The results can best be understood by inspection of the top half of Table 4, which reveals one cell entry which is strikingly lower than any other. This cell mean represents the experimental condition of arbitrary connection, real time question, Block S-R.

The triple interaction was unexpected and difficult to interpret, but it clearly implicates some differences in processing strategies. The general finding that real time is an easier basis of responding than story time may be due to the fact that the story need not be processed as extensively. The semantic relationships between events do not have to be encoded, subjects need only abstract enough information to create a representation of input order. The test on story time clearly poses more difficulty since the semantic markers must be taken into account. It appears that if this more difficult task is presented first, subjects find the real-time task easier, provided the story contains arbitrary connections between events. If the ordering is logical, subjects seem to have difficulty switching from a semantic processing strategy to one which ignores the semantic relationships existing between the events. It is more difficult to give the "wrong" answer (ignoring the flashback) when it goes against an ordering reinforced by prior knowledge. In the case of arbitrary stories, subjects can more easily ignore the semantic components of the ordering because they are only based on episodic contiguity. In this condition, then, subjects benefit from having had practice on the more difficult task first and show a large decrease in latencies.

The error data are somewhat easier to interpret because the triple interaction was not significant. Again, the effect of primary interest, test question, was reliable, $F_1(1,26) = 28.81$, $MS_e = .019$; $F_2(1,45) = 5.85$, $MS_e = .010$. More errors were made when the questions involved underlying order of occurrence rather than input sequence. The interaction of question and block was reliable on the item analysis of variance, $F_2(1,45) = 5.31$, $MS_e = .010$. The difference in error rates between real time and story time questions was very small for three of four comparisons; however, on arbitrary passages tested in Block S-R the difference was 22%. This outcome parallels the response latencies: error rates were highest when the harder story-time questions were presented first; they dropped markedly when the easier real time was tested. A slightly different pattern emerges in the subject analysis, where the question by connection interaction was reliable, $F_1(1,26) = 13.51$, $MS_e = .01$. When the events were arbitrarily connected, there were 22% fewer errors on real time questions, but when logical connections existed between the events, there were only 6% fewer errors. This again indicates that it is harder to ignore semantic markers when they are based on pre-experimental knowledge than when they only have an episodic basis. This effect obtained regardless of block order.

In summary, these data provide further evidence that the initial representation of a story preserves the temporal record of input and rule out the explanation that the effect occurs only because real time is consistent with story time. Surface order retains its advantage even when it is inconsistent with the underlying semantic organization of the story. The interactions with block order suggest that subjects were adopting task-specific strategies. Nevertheless, the fact remains that subjects were generally better at making judgments about order of input than about underlying order.

Experiment 4

It is possible that temporal organization exerts its influence only on an immediate test. A number of studies have shown that surface information is well-remembered immediately after processing but with interference and/or the passage of time, people come to rely on a more general memory of meaning (e.g., Anderson, 1974; Garrod & Trabasso, 1973; McKoon, 1977; Smith & McMahon, 1970). Experiment 2 suggests at least some persistence, but how fragile is this temporally-ordered memory? Would it disappear if the test was not only delayed but an interference task was introduced? This possibility was examined in the present experiment using a paradigm similar to that of Experiments 1 and 2. If real-time information is but briefly retained, then the advantage of chronological over flashback stories should be eliminated. However, if temporal organization has some robustness, then differences should still obtain. A 10-second interference task was introduced between story and probe presentation and consisted of detecting spelling errors in a list of difficult-to-spell words. The duration of this task is admittedly short, but a longer task destroys the sensitivity of the latency measure. A preliminary study using a 15-second interference task resulted in large but equivalent increases in errors and response times on both sequence types. As it was, a few procedural modifications were necessary to ensure better-than-chance accuracy: the number of stories was reduced to prevent excessive fatigue; reading times were subject-controlled and maximum response times were increased.

Method

Materials. The stimulus materials were the same as those used previously, but logical stories were not included. Subjects received a total of 40 stories, 8 practice and 32 test. Half were in chronological sequence and half flashback. This reduction in the number of passages was an effort to prevent subject fatigue in light of the difficult distractor task. The arbitrary stories were chosen over the logical to eliminate effects of prior knowledge. A filled interval might conceivably produce sufficient forgetting that subjects would adopt a guessing strategy, which would lead to greater success on logical than on arbitrary passages. Such a guessing strategy would obscure differences between chronological and flashback paragraphs which might otherwise be apparent.

The probes were the same as those used previously, but they were displayed in a different format. The phrases were arranged one on top of the other rather than appearing on a single line. The task was to decide whether the event on top preceded the event on the bottom in order of occurrence in the story. Twenty of the test probes required true decisions, and 12 false.

Eight hundred words were selected for use in the interference task, drawn from a collection of difficult-to-spell words (Callihan, 1957). Half of the words were spelled correctly and half contained an error.

Procedure. The experiment was under the control of the PLATO computer system at the University of Illinois. Subjects received detailed instructions in written form, and were given an opportunity to ask questions of the experimenter. Each subject sat at a video terminal equipped with a typewriter-like keyboard. Subjects were instructed to hold their right index finger above the "y" key, to be used for a "yes" (true) response, and their left ~~index finger~~ over the "n" key, to be used for a "no" (false) response. The sequence of steps in the experiment was as follows: subjects signed onto the system individually and were instructed via the computer to press the key labeled "next" in order to see the first story. Once they did so, the story was written onto the screen. The subjects were permitted to read through the story at their own pace (with a maximum of 32 seconds), indicating by a key press when they had finished. Reading times were recorded by the computer. The key press initiated the interference task. Twenty words were displayed on the screen, in four columns of five words each. Subjects proceeded down the columns, pressing the "y" key if the word was spelled correctly, the "n" key if it was incorrect. Preliminary testing showed it was virtually impossible to respond to all 20 words within the allotted time. At the end of 10 seconds, the list was erased and the word "Probe" appeared, followed by the probe itself. Taking into consideration the time required by the computer to change displays, the delay between story and probe presentation was actually about 15 seconds. Subjects responded "y" if the order of events in the probe matched the underlying order in the story and "n" if not; the response was printed on the screen. If a subject failed to respond within 15 seconds, a "time-up" message appeared. This 3-step sequence constituted one trial. Subjects then pressed "next" for presentation of the next passage, initiating trial 2. This sequence was repeated through eight practice trials, after which an opportunity for questions was provided. The subjects then self-initiated the 32 test trials. Responses and response times were recorded by the computer. A 2-minute rest period was provided after 16 trials, during which subjects watched an animated display on the PLATO screen. The entire session lasted about 50 minutes.

Subjects. Subjects were 20 University of Illinois undergraduates enrolled in an educational psychology course. Participation in the experiment partially fulfilled a course requirement.

Results and Discussion

The dependent measures of interest were reading times, response times, and error rates. No data were collected on the interference task, but the experimenter observed subjects for compliance with the instructions. The differences between chronological and flashback means were analyzed using

t-tests for correlated samples. A summary of the results is presented in

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Insert Table 5 about here

Table 5. The experiment replicated the results of Experiments 1 and 2 in that subjects required more time to respond to the probe on flashback sequences than on chronological, $t(19) = 5.25$, and flashback sequences resulted in higher error rates, $t(19) = 3.69$. Quite clearly, the interference task did not eliminate the differences between chronological and flashback sequences. This indicates that real time has some persistence in the memory representation.

Analysis of the reading times revealed that subjects required more time to read flashback than chronological sequences, $t(19) = 2.18$, suggesting that the inverted sequences were more complex and/or difficult to comprehend. It is true that the flashback stories generally contained one more word than the chronological ("before that" vs. "then"), but it is unlikely that this would produce significantly longer reading times. More importantly, it is also unlikely that the increased reading times reflected an attempt to reorganize the story to conform to its underlying sequence. Had this strategy been adopted, the response times and error rates would not have been greater on flashback sequences. One possible explanation for the increase is that subjects required additional time to identify the antecedent of the pronoun "that" in the flashbacks (Garrod & Sanford, 1977).

The present experiment substantially weakens the argument that subjects maintain a surface order representation for a brief period of time, but that they rely primarily on meaning. Had this been true, the interference task should have eliminated the transitory surface representation, leaving the underlying representation intact. Theories which stress the role of semantic structure in memory representation would predict that the story is reorganized during processing to conform to the underlying sequence, resulting in formally equivalent representations for both types of input. Therefore, assuming that the interference task displaced the competing surface representation, performance levels on the delayed test should be comparable. The fact that the advantage of chronological stories was not eliminated poses a problem for this theoretical position. The temporal record of input apparently exerts a greater organizing influence than the temporal relationships inherent in the meaning of the story.

General Discussion

The present series of experiments has demonstrated that episodic information, specifically information about the temporal order of input, has a strong influence on the immediate representation of simple stories. Experiment 1 showed that people are faster and more accurate at answering questions about the order events took place in a story when the order of mention was the same as the order of occurrence. This was also observed in the second experiment when subjects were given an opportunity to extract and rehearse the underlying story sequence. The third experiment demonstrated that people are better at making decisions on the basis of input sequence than underlying sequence. The advantage of input order is not simply due to retention of a fragile surface representation, since the effect remains with an interference task in Experiment 4.

The primary goal of the experiments, to demonstrate the influence of input sequence on memory of simple stories, has been realized. A secondary goal was to demonstrate an effect of the type of connection between events. It was expected that when events within a story are logically related, decisions would be easier than when events are linked by temporal contiguity alone. This prediction was based on the assumption that the sequence of events in such a story is compatible with real world sequences and that the possibility of relating the sequence to prior knowledge allows the subject to create a more coherent representation of the story. The events in an arbitrarily-connected story are only linked with respect to that particular episode, and so underlying order information is harder to access. The results of Experiments 1 and 2 were consistent with expectations: response times were shorter and error rates were lower on logical stories. In Experiment 3, the interactions with block order make the effect of connection difficult to interpret.

Given that logical stories were easier to deal with than arbitrary, it is somewhat surprising that there was no evidence of an interaction with sequence. Because the underlying order of events in a logical story conforms to an expected sequence, one might expect less difficulty on flashback sequences than when the events are arbitrarily ordered. In other words, subjects should be more likely to create a representation that is integrated with respect to the underlying order. The absence of an interaction strengthens the argument against the claim that stories are re-structured during processing to conform to an ideal schema (e.g., Kintsch et al., 1977). The facilitatory effects of logical connections probably occurred at the time of test; it was easier to access the correct ordering because prior knowledge could be used as well as episodic information. This advantage operated equally on chronological and flashback sequences.

The present experiments also have bearing on the issue of paraphrase invariance. Several models of memory contend that information is represented in an abstract propositional format, such that a given conceptual idea has a common representation regardless of its exact surface realization. On this view, chronological and flashback versions of the same story should have the same formal representation, since they contain the same underlying ideas and differ only in surface expression. However, the consistent differences in response times and error rates for chronological and flashback sequences argue against this position. Without posing an alternative model, the modest claim can still be made that the representations differ.

One problem with the invariance model arises from the lack of a precise definition for paraphrase (Anderson, 1976). Although the chronological and flashback versions of a given story seem to have the same general meaning, it is not clear they are actually paraphrases of one another. Miller and Johnson-Laird (1976) argue that subtle differences in meaning exist depending on the way a temporal relationship is expressed. For example, different presuppositions are involved depending on whether the subordinate clause of a sentence contains the word "before" or "after." Similarly, Stein (in press) suggests that flashbacks may alter the number and types of inferences that are made during reading. Another problem for the invariance model is the content-free aspect of prose known as signalling (Meyer, 1975). A flashback could be regarded as a form of signalling; it does not add new content or relationships to the text, but increases the salience of particular events, perhaps imparting a different perspective on the story. This technique serves an important stylistic function, but its effects on memory have not been considered.

In conclusion, the present experiments attest to a weakness in models of prose representation which emphasize meaning. Most people undoubtedly do try to make sense of things while reading, but it is unlikely that they engage in the sophisticated restructuring strategies for which they are credited. Not only does the memory representation preserve the order of input, it also contains other surface characteristics of text. Though not wishing to claim that people have verbatim memory, even for stories as short as those used in these experiments, it is clear that they remember much more specific information than an abstract propositional representation would allow.

The experiments also have some practical implications for educators. It is generally agreed that meaning is not inherent in a text, but rather is constructed by the reader in an interactive process involving both surface information and world knowledge. Clearly, an assessment of the knowledge a reader has acquired from text must not restrict itself to tests of verbatim memory. However, the present experiments indicate that information derived from a text is not re-structured into a semantically-consistent representation during reading, but rather that it is organized according to the order of input. Therefore, it should not be assumed that the reader automatically integrates related ideas into a coherent structure. The proficient reader probably can reconstruct a meaningfully organized text, but the less skilled reader may have difficulty establishing interconnections among ideas that are not presented contiguously in the text. This implies that comprehension will be facilitated if information is presented in an order that is consistent with the logical flow of ideas.

The experiments also provide further evidence that people make use of prior knowledge in new learning situations. Subjects' responses were faster and more accurate when the to-be-remembered information conformed to a familiar and predictable situation. Brown and Murphy (1975) have demonstrated a similar facilitation in young children; the present experiments indicate that it does not diminish with the increased memory skills of adults. An obvious implication for education is that efforts should be made to present information to students in such a way that it makes contact with existing knowledge.

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Footnotes

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[1]It should be noted that these passages do not conform to an ideal story structure because they are not strictly goal-oriented and lack one or more types of information required by story grammars (e.g., Stein & Glenn, in press). A more appropriate label might be "narrative," but I find it simpler to refer to them as stories.

[2]In order to corroborate the psychological validity of this dichotomy, a post-hoc norming study was carried out. Materials were constructed such that on each of the 56 test stories, the first and last sentences remained in their appropriate positions, but the three middle sentences were rearranged in a random order. All temporal markers were eliminated from the sentences so as not to provide clues about ordering. In addition, all pronouns were

replaced by nouns so that referential style would not serve as an ordering cue. Ten subjects were instructed to arrange the three middle sentences into the sequence they thought made the "best" story. They were told that in some cases, one ordering would clearly be the best, while in other cases, no one ordering would seem better than another. They were also instructed to classify the story as containing either a logical ordering of events or an arbitrary ordering.

Performance on the ordering task was as expected. On those stories classified as logical, subjects consistently ordered the events in the expected sequence, but there was no particular pattern in arranging the events in the arbitrary stories. In addition, there was 95% agreement on the classification task. Thus, the stories do conform to the guidelines by which they were constructed.

[3]The dependent variable in the subject analyses was p (error), while in the item analyses it was number of errors, thus accounting for the discrepancies in the magnitude of the MS_e's.

Table 1

Examples of Stories and Probes

Arbitrary Connections

Chronological. Dan's friends asked him to help them move out of their house. Dan dropped a filing cabinet, breaking the railing on the stair. Then, he knocked a dresser into the wall and cracked the plaster. Next, he dropped a porcelain lamp which shattered into tiny pieces. Dan was not a good moving man.

Flashback. Dan's friends asked him to help them move out of their house. He knocked a dresser into the wall and cracked the plaster. Before that, Dan dropped a filing cabinet, breaking the railing on the stair. Later, he dropped a porcelain lamp which shattered into tiny pieces. Dan was not a good moving man.

Probe. broke railing.........cracked plaster (true)

Logical Connections

Chronological. Mary's annual visit to the doctor was quite traumatic. She had to spend two hours in the waiting room with a scolding mother and four whining children. Then the nurse tried to take a blood sample and couldn't find a vein until the 7th try. Later, Mary discovered that someone had stolen her coat from the closet. She swore she'd never go back for another check-up.

(Continued on following page)

Table 1 (continued)

Flashback. Mary's annual visit to the doctor was quite traumatic. The nurse tried to take a blood sample and couldn't find a vein until the 7th try. Before that, Mary had to spend two hours in the waiting room with a scolding mother and four whining children. Later, Mary discovered that someone had stolen her coat from the closet. She swore she'd never go back for another check-up.

Probe. whining children..........blood sample (true)

Table 2

Mean Response Times (in msec) and Error Probabilities

in Experiment 1

	Sequence		
	Chronological	Flashback	Mean
True decisions			
Connection			
Arbitrary	3327 (.09)	3747 (.19)	3537 (.14)
Logical	3137 (.04)	3550 (.11)	3344 (.08)
Mean	3232 (.07)	3649 (.15)	
False Decisions			
Connection			
Arbitrary	3442 (.04)	3973 (.23)	3708 (.14)
Logical	3244 (.03)	3607 (.12)	3426 (.08)
Mean	3343 (.04)	3790 (.18)	

Table 3

Mean Response Times (in msec) and Error Probabilities

in Experiment 2

	Sequence		
	Chronological	Flashback	Mean
True decisions			
Connection			
Arbitrary	3910 (.04)	4444 (.16)	4177 (.10)
Logical	3571 (.04)	3989 (.18)	3780 (.11)
Mean	3740 (.04)	4216 (.17)	
False Decisions			
Connection			
Arbitrary	3722 (.06)	4690 (.20)	4206 (.13)
Logical	3662 (.05)	4301 (.18)	3982 (.12)
Mean	3692 (.06)	4496 (.19)	

Table 4

Mean Response Times (in msec) and Error Probabilities

in Experiment 3

	Test question		
	Real time	Story time	Mean
True decisions			
Block order S-R			
Connection			
Arbitrary	3085 (.02)	4269 (.26)	3677 (.14)
Logical	4205 (.12)	4301 (.15)	4253 (.14)
Mean	3645 (.07)	4285 (.21)	
Block order R-S			
Connection			
Arbitrary	3935 (.03)	4343 (.23)	4139 (.13)
Logical	3775 (.05)	4150 (.13)	3962 (.09)
Mean	3855 (.04)	4247 (.18)	

(Continued on following page)

Table 4 (continued)

	Test question		
	Real time	Story time	Mean
False Decisions			
Block order S-R			
Connection			
Arbitrary	3873 (.15)	4695 (.30)	4284 (.23)
Logical	3892 (.19)	4252 (.21)	4072 (.20)
Mean	3883 (.17)	4474 (.11)	
Block order R-S			
Connection			
Arbitrary	4064 (.12)	3933 (.12)	3999 (.12)
Logical	4139 (.25)	4736 (.18)	4438 (.22)
Mean	4102 (.19)	4335 (.15)	

Table 5

Summary of Results in Experiment 4

	Sequence	
	Chronological	Flashback
True decisions		
Response times (sec)	5.176	5.855
p (error)	.04	.18
Reading times (sec)	23.597	24.472
False decisions		
Response times (sec)	5.272	5.706
p (error)	.11	.22
Reading times (sec)	22.835	24.190

Appendix

Summary of Significant Statistical Tests on False Decisions

Experiment 1

Response Times

Sequence: $F_1(1,72) = 7.38$, $MS_e = 514,575$

Connection: $F_2(1,19) = 4.26$, $MS_e = 256,891$

p (error)

Sequence: $F_1(1,72) = 16.39$, $MS_e = .0228$

$F_2(1,22) = 18.04$, $MS_e = 2.11$

Connection: $F_2(1,22) = 4.22$, $MS_e = 2.11$

Experiment 2

Response Times

Sequence: $F_1(1,36) = 11.57$, $MS_e = 558,004$

$F_2(1,19) = 5.42$, $MS_e = 569,381$

p (error)

Sequence: $F_1(1,36) = 5.77$, $MS_e = .03231$

$F_2(1,19) = 7.76$, $MS_e = 1.09$

(Continued on following page)

Experiment 3

Response Times

Question: $\underline{F}_1(1,26) = 9.29$, $\underline{MS}_e = 488,329$

$\underline{F}_2(1,44) = 4.52$, $\underline{MS}_e = 419,316$

~~Connection x Block: $\underline{F}_1(1,26) = 5.97$, $\underline{MS}_e = 473,974$~~

$\underline{F}_2(1,44) = 7.98$, $\underline{MS}_e = 419,316$

Question x Connection x Block

$\underline{F}_1(1,26) = 7.80$, $\underline{MS}_e = 303,582$

$\underline{p}$ (error)

Question: $\underline{F}_2(1,44) = 4.23$, $\underline{MS}_e = .020$

Connection x Block: $\underline{F}_1(1,26) = 5.92$, $\underline{MS}_e = .017$

Experiment 4 (Sequence)

Response times: $\underline{t}(19) = 1.89$

$\underline{p}$ (error): $\underline{t}(19) = 2.24$

Reading times: $\underline{t}(19) = 2.38$

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